

Simulation Based Routing Protocols Evaluation for IEEE 802.15.4 enabled Wireless Sensor Networks

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Abstract-Wireless sensor network (WSN) is emerging as a major research field in computer networks over the last decade due to its wide variety of embedded real time applications. Sensor networks have infrastructure-less architecture because of frequently varying topology and link status. Routing is an extremely challenging task for battery-powered resource-constrained WSN, since it is main cause for energy depletion and energy must be utilized prudently to enhance lifetime for sensor networks. This drives a myriad of research efforts aiming at efficient data dissemination. In this paper we analyze how efficiently MANET specific routing protocols OLSR (Optimized Link-State Routing protocol), DYMO (Dynamic MANET On-demand) and ZRP (Zone Routing Protocol) perform in IEEE 802.15.4 enabled wireless sensor networks and evaluate their simulation results using Qualnet simulator. Several simulations were carried out under varying network size and offered load for performance evaluation and relative comparison of protocols is reported in terms of average end to end delay, throughput and jitter.

Index Terms- OLSR, DYMO, ZRP, WSN

I. INTRODUCTION

Wireless sensor network (WSN) is a self organized network typically comprises of massive number of densely deployed resource constrained sensor nodes spatially distributed over a geographical region. Recent studies [1], [2] shows that the employment of WSNs for industrial applications is expected to increase at an exponential pace in coming years with their intrusion in the fields of logistics, automation and control. They have emerged as a new class of large scale networks of embedded systems with limited communication, computation and energy resources [3]. Basically, sensors are tiny nodes capable to sense, compute and communicate wirelessly so that they can respond to a particular event in a monitored environment. Sensors aim at collaborative effort to gather and share information about a particular phenomenon and forward the processed information to sink node. Sink nodes acts as a gateway between sensors and end user. End user can retrieve information by querying WSN or gathering information from sink nodes. However, main constraint is finite energy supply because sensor operates on battery and deployed over hostile locations, causing it very much difficult to recharge exhausted battery, end up partitioning from network. Thus, it is critical and challenging to design long lived WSN with the energy constraints [4].

The rest of this paper is organized as follows: Section II provides an overview of routing protocols in sensor networks. Section III presents related work. A detailed description of various routing protocols is provided in Section IV. Simulation results and performance analysis is shown in Section V. Finally section of paper draws Conclusion.

II. ROUTING IN WSN

Routing in WSN is very critical being major cause for depletion of energy of sensor nodes is data dissemination. Therefore, while traditional networks aim to achieve high quality of service (QoS) provisions, sensor network protocols must focus primarily on power conservation [5]. To deal with this, an extensive amount of research was done and still going on towards the optimization of data dissemination for sensor networks. One promising solution for optimal use of energy is to opt for energy efficient routing protocols. Sheer numbers of inaccessible and unattended sensor nodes, which are prone to frequent failures, make topology maintenance a challenging task [5]. This implies that routing protocol must also possess self-adaptation capabilities to frequently varying network topology and link status. On the basis of route determination, routing protocols are categorized in three ways: proactive (Table driven), reactive (On Demand) and hybrid routing protocols. Proactive protocol discovers the network topology and computes the routes are pre-determined well earlier than it is actually required. WSN dynamic topology necessitates revision of all routing tables periodically. On other hand, a reactive protocol doesn't require prior route discovery or knowledge of network topology for data dissemination; route is setup only when traffic flow has been started addressed to a destination. Hybrid protocols amalgamate advantages of proactive and reactive protocols.

III. RELATED WORK

Here, we are evaluating some of the simulation studies presented earlier for protocol comparison for sensor networks. Earlier, *Pore Ghee Lye* et. al. in [6] performed analysis for AODV, OLSR and DSDV and evaluated comparison. Their Simulation results showed that OLSR comes up as best protocol for WSN. It consistently outperformed AODV and DSDV. Its routing overhead is compensated by its best performance for packet delivery ratio with increasing traffic load. Performance comparison by *vinay kumar* et. al. in [7] demonstrated superior performance of XMESH over AODV and DYMO in energy consumption in transmit mode,

receiving mode, % of time in transmit mode and received mode. DYMO outperforms AODV and XMESH in energy consumption in idle mode. Andreas Lewandowski et. al. presented simulation results of comparison among AODV and OLSR in [8] determined that AODV has higher average end to end delay as compared to OLSR due to route determination process. OLSR lacks from AODV in terms of mobility support due to periodical route maintenance of OLSR's proactive nature. They showed OLSR consumed slightly more energy than AODV to maintain overall network topology in each node. Simulation system for WSNs using ns-2 was implemented by Tao Yang et. al. in [9] for AODV and OLSR. Simulation results conclude that in AODV as number of sensor nodes increases Goodput decreases, due to increased traffic for route determination. Whereas in OLSR, as number of nodes increased so is the Goodput. The Goodput of AODV is better than OLSR when the transmission rate is lower 10pps, after election of MPRs, Goodput of OLSR is better than AODV. Routing protocols AODV, DSR, DSDV, OLSR and TORA evaluated in [10] by Zhongwei Zhang et al., showed that with single source except TORA all other protocols have acceptable routing overhead. Except DSDV packet delivery ratio of all other protocols is above 60%, where DSDV possessing low packet delivery ratio. With increase in number of sources, packet delivery ratio falls significantly, except AODV. Protocol comparison and evaluation of AODV, DSDV and DSR performed by Nandkumar Kulkarni et al. in [11] resulted that DSR has best performance in energy consumption as compared to other two protocol. AODV showed moderate energy consumption, definitely better than DSDV. In the literature, these routing protocols were compared for MANETs. However, to best of our knowledge these protocols are not yet evaluated for sensor networks. Also, ZRP is not compared with any other routing protocols in WSN. All this persuade us to conduct a study on these routing protocols for WSNs and analyze their merits and demerits.

IV. ROUTING PROTOCOLS ANALYSIS

A. OLSR

OLSR (Optimized Link-State Routing protocol) being a proactive protocol, routes are already available in routing table, so no route discovery delay is associated. OLSR is an optimization of classical link state routing protocol. Key concept here is MPRs (MultiPoint Relaying). Instead of allowing each node to broadcast topology messages only selected nodes (MPRs) are used to broadcast topology information during flooding process. This significantly reduces the overhead caused by flooding in link state routing protocol. OLSR is characterized by two types of control messages: neighbourhood and topology messages, called respectively Hello messages and Topology Control (TC) messages [9]. HELLO messages are used to identify local topology information, setting TTL to 1. Now, nodes perform distributed election to elect a set of MPRs from its neighbours based on fact which neighbour provide shortest forwarded path to all of its 2 hop neighbours. To diffuse topology

information, nodes periodically exchange Topology Control (TC) message [12] with their neighbours. Upon receiving this information every node in network is aware of the fact which MPR to follow if they wish to communicate with one of the MPR's selector.

B. DYMO

The Dynamic MANET On-demand (DYMO) [13] routing protocol is a simple and fast routing protocol for multi-hop networks. DYMO reactive by nature very well handles dynamic topology networks. Also, storage of active routes make their suitability for memory constrained networks like WSNs. DYMO comprises of two basic operations: Route Discovery and Route Maintenance. In Route Discovery, originating node inject a RREQ (Route Request) message into the network to compute route to target. As the RREQ message travels from one hop to another each one set its path to originator. When target receives RREQ it responds with RREP (Route Reply) message. Each intermediate hop that receive RREP message set its path for target. When originator receives RREP message, route has been established in both directions. In route maintenance phase, each hop between originator and target keep an eye on route. Whenever target is unapproachable, originator is notified with RERR (Route Error) message; it deletes the existing route and disseminates a new RREQ message in search of a new route for that destination in network. Sequence number enables nodes to determine the order of DYMO route discovery messages, thereby avoiding use of stale information [14].

C. ZRP

Zone Routing Protocol or ZRP [15] was the first hybrid routing protocol with both a proactive and a reactive routing component. ZRP comprises of two sub-protocols: IARP (Intra-zone Routing Protocol) proactive by nature is used for communication within zone and IERP (Inter-zone Routing Protocol) which is reactive is used for communication within zones. Whenever communication is required within zone pre determined routes are accessed through routing tables, no latency is introduced. Communication between zones is performed reactively, computing routes on demand only. For destination beyond zone route request is forwarded to border node of zone. Border node check its local zone if destination not available forward it to its border nodes. If destination is available in local zone route reply is sent back to sender. Size of zone plays a decisive role. A large radius will favour the proactive routing protocol, optimal for slow moving traffic or large amount of traffic [16].

V. SIMULATION AND PERFORMANCE ANALYSIS

To evaluate the effectiveness and performance of DYMO, OLSR, ZRP routing protocols in wireless sensor networks under variable network size and traffic loads, a simulation study is performed.

A. Simulator

We use Qualnet 5.0.1 [17] as a simulator to model and simulate our scenario architecture for Zigbee 802.15.4.

QualNet is the first commercial network simulator targeting at wireless solutions. It is an integrated, versatile, easy-to-use graphical user interface for creating and simulating a network. Typically, users can also customize the simulator to fulfil their specific analysis needs.

B. Simulation Environment

We have designed various scenarios with nodes ranging from 5 to 200 deployed in field configuration of 1500x1500 m². Traffic load is variable in each scenario because of varying number of CBR (Constant Bit Rate) traffic sources. Simulation time for scenario is set to 100 seconds. We have used IEEE 802.15.4 MAC and physical radio. Antenna Model is Omni-directional and height is 1.5m and 0 dB antenna gain. The source node generates constant bit rate (CBR) traffic of 100 packets of 72 bytes. Table I summarizes the simulation parameters.

TABLE I. SIMULATION PARAMETERS

Parameter	Values
Routing Protocols	DYMO, OLSR, ZRP
Shadowing Model	Constant
Pathloss Model	Two-Ray
Simulation area	1500 x1500 m ²
Data packet size	72 Byte
Data packet rate	100 packets/second
Propagation limit	-111.0 dBm
Energy Model	MicaZ
Modulation Scheme	O-QPSK
MAC Protocol	802.15.4
Placement Model	Random
Simulation time	100 sec
Traffic Type	Constant Bit Rate

C. Performance Index

To evaluate effectiveness of routing protocols analysis is done with the help following performance metrics:

1) *Network Throughput* refers to maximum number of bits may be delivered over a physical or logical link, pass through a certain network node or entity in a second.

2) *End-to-end delay* refers to the time taken for a packet to be transmitted across a network from CBR source to application layer of destination.

3) *Average Jitter* refers to variation in the delay of received packets even if they are sent at same time. This may be due to network congestion, improper queuing, or configuration errors.

D. Simulation Results

Different scenarios are executed to evaluate how well routing protocols scale to varying network size and offered load. Network scenarios are designed using Random waypoint model. Results are compiled from 7 different simulations, where each scenario has variable number of node and traffic sources. Simulation results for routing protocols are as shown in Figure 1, Figure 2 and Figure 3 for above mentioned metrics:

1) *Average End to End Delay*: Figure 1 illustrates average end to end delay by varying number of nodes and traffic sources. Simulation result demonstrates end to end delay remains negligible for small number of nodes. As number of

nodes rises to 75, it drives significant increase in delay, even increase of CBR sources not help out. DYMO definitely predominate with lowest delay of 16sec as compared to OLSR and ZRP with delay of 24 sec. This may be due to frequent changes in network topology resulting in prior route discovery under proactive scheme.

2) *Throughput*: Figure 2 depicts achievable throughput as a function of network size and traffic sources, all protocols follow decrease in throughput. Although, DYMO prevail over other two protocols, its throughput drops significantly after 100 nodes. OLSR and ZRP perform well upto 50 nodes; results in sharp drop as further increase in network size introduces lot of control overhead due to their proactive nature.

3) *Jitter*: Figure 3 demonstrate impact of varying offered load and size on jitter. Here, again DYMO comes up as best performer from other two protocols. As we can observe that after scaling network upto 100 nodes, instant rise in jitter for all the protocols. This is due to that fact that as network size increases so is control overhead of Query messages, consumes more time to reconfigure the route.

CONCLUSION

This paper demonstrates routing protocols evaluation and comparison for WSNs through Qualnet simulator. To test efficiency of routing protocol, we analyzed and compared relative performance of DYMO, OLSR and ZRP on the basis of parameters average end to end delay, throughput and jitter as a function of network scalability and offered load. From simulation results, we concluded that DYMO comes up as finest routing protocol for WSNs, outperforming both OLSR and ZRP because of its simplicity and reactive nature. We observe that performance of OLSR and ZRP was not up to the mark throughout all metrics because of their control overhead associated with their proactive component. For future work, we plan to perform more extensive simulation of protocols on other parameters and to propose some improvisation of protocols to accommodate high topology changes and scalability.

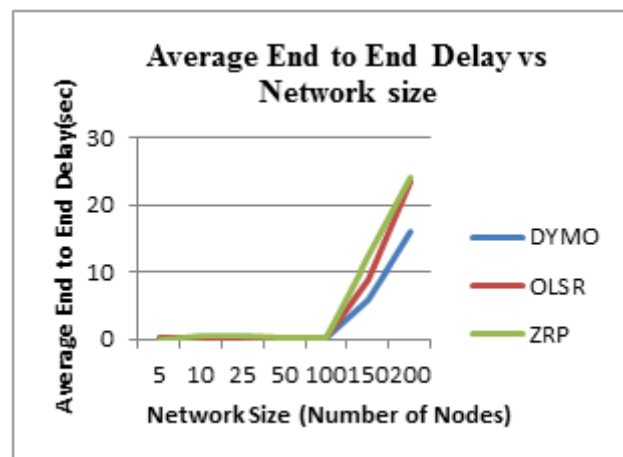


Figure 1. Average End to End Delay on different network sizes

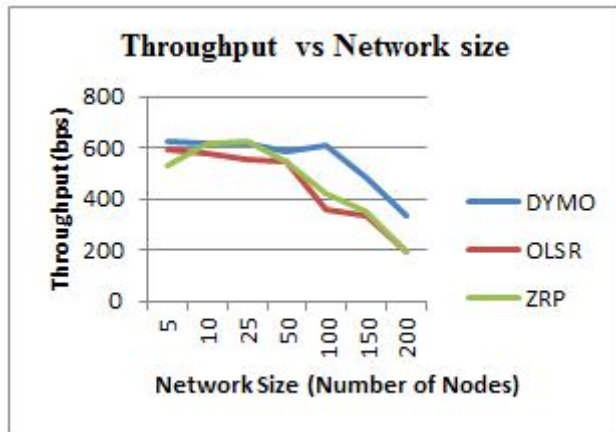


Figure 2. Throughput for different network sizes

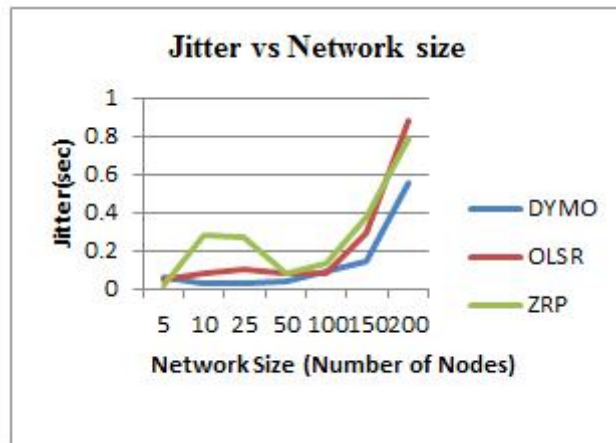


Figure 3. Jitter on different network sizes

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